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Chun Kuang[2] Jiawen Yang[3] Wenyu Zhu[4]

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Abstract

Banks' ability to convert liquidity into lending depends crucially on the various regulatory constraints they face. This paper investigates the differential lending responses of banks with varying levels of reserves, and their impact on the real economy. The distribution of reserves within the banking system became significantly more dispersed during the quantitative easing (QE) periods. Loan growth for those more liquidity-constrained does not vary meaningfully with liquidity changes, despite abundance at the aggregate level. Consequently, our findings imply that the uneven bank reserve distribution may exacerbate the spatial disparities in bank lending and regional economic development through differential lending responses of banks in different parts of the reserve distribution.

JEL Classification: G20, G21
Keywords: reserve holding, bank lending, quantitative easing, reserve distribution

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1.Introduction

High levels of reserve holdings have become the new norm in the U.S. banking sector due to the implementation of quantitative easing (QE) policies after the financial crisis. The Federal Reserve Board eliminated reserve requirements in March 2020 under the current "ample reserves regime." The collapse of Silicon Valley Bank serves as a reminder of the importance of liquidity management in an era marked by excess liquidity. In addition to the dramatic increase in the aggregate reserve level, the distribution of reserves within the banking sector has also become significantly more dispersed. While all banks have increased their cash and reserve holdings during this period, the increase was much larger for banks at the upper end of the distribution, with the interquartile range more than doubling during this period. In this paper, we examine the differential lending responses of banks with varying levels of reserves, and the distributional impact on the real economy.

Prior to the QE period, all reserves were held on banks' balance sheets solely to satisfy the reserve requirements, rendering them effectively "unloanable". A combination of scarce lending opportunities post crisis, stringent regulatory requirements, and interests paid on reserves by the Fed, has reshaped the trade-off concerning reserve holding for banks. Moreover, asymmetric adjustment costs could have also contributed to the high levels of reserve holdings post crisis, as adjustment costs associated with divestment during economic downturns are usually larger. These large amounts of reserves held by banks, in theory, could allow them to respond more promptly to changes in local economic conditions. This, however, only holds true under the assumption that other liquidity demands and relevant regulatory requirements, are met.

Intrigued by the increased dispersion in reserve holdings across banks, we examine the dynamics of loan growth in response to liquidity changes for banks with varying levels of reserves, and the impact of such differential loan growth on the real economy across space. We find that loan growth for those more liquidity-constrained (i.e., with lower levels of reserves) does not vary meaningfully with liquidity changes, despite abundance in the aggregate level. Only when banks are working with ample reserves, does loan growth become more sensitive to changes in banks' overall liquidity levels. This set of results highlights the significance of the increased dispersion in reserve distribution across banks, as the uneven loan growth across banks could translate into greater spatial disparity in regional recovery and development.

To demonstrate the robustness of our finding, we adapt the demand control method proposed by Degryse et al. (2019), and estimate our model at the loan level using DealScan data with borrower fixed effects, loan type fixed effects, and industry–location–year fixed effects. We also construct novel measures of liquidity constraint using individual bank's exposure to the hardest-hit housing markets in the financial crisis using HMDA data, and show that our results are robust to alternative definitions of liquidity constraint as well as sample restrictions. Liquidity-constrained banks appear less responsive in their lending increase to positive liquidity shocks during the QE episodes, as there is a multitude of reasons for banks to hold liquidity without increasing lending during the financial crisis. We summarize the evolution of reserve distribution in the banking sector in Section 2, in the hope of better understanding its potential impact on lending for banks in different parts of the reserve distribution.

Importantly, we find that the uneven distribution of reserves within the banking sector as a result of the QE policy has rather diverse effects on regional development across space. Counties with a higher market share of reserve-rich banks experience more local business growth. Additionally, industries that are more dependent on external financing benefit more from the local presence of these high-reserve banks, as they are more active in converting excess

liquidity increases into new lending. We find no such association between local business growth and the market share of large banks in the county, suggesting that the relation we uncover is distinct from a bank-size effect or some unobservable differences in markets dominated by large banks.

Our study adds to the growing literature on banks' reserve holding after the 2008 financial crisis. Stulz et al. (2022) investigate the determinants of excess reserve holding of commercial banks and find that large banks tend to hold more liquidity compared to smaller banks due to regulatory changes, including the more stringent liquidity and capital requirements after the financial crisis. Acharya and Rajan (2022) and Diamond et al. (2022) both look at the unintended consequence of excess reserve holding as a result of the QE policies. Acharya and Rajan (2022) find that reserve hoarding may exacerbate liquidity shortage in the banking system and therefore dampen the effectiveness of QE policy in increasing bank lending. By estimating a structural model, Diamond et al. (2022) propose a "reserve supply channel" of QE and show that excess reserve holding may crowd out bank lending due to balance sheet costs. We show that the unequal reserve distribution across banks documented in the literature could potentially translate into uneven loan growth across space due to differential lending responses between high-versus low-reserve banks.

The general question we address is also related to the transmission of unconventional monetary policy. Our study is related to the literature on the credit channel of unconventional monetary policies, especially those with micro-level evidence. Rodnyansky and Darmouni (2017) and Chakraborty et al. (2019) emphasize the net-worth channel of QE, which focuses on the changes in the value of mortgage-back securities (MBS) held on banks' balance sheets.[1][5] Using a difference-in-differences approach where "treated banks" are those with relatively larger amount of MBS or Treasuries prior to the QE period, Rodnyansky and Darmouni (2017) find tha treated banks increase their lending more in response to the Fed's large-scale asset purchases (LSAPs). Our research differs from but complements the work of Rodnyansky and Darmouni (2017) and Chakraborty et al. (2019), as we focus on the banks with different levels of reserve holdings and study the distributional impact on the real economy. While only a limited number of primary dealers held large amounts of MBS prior to the crisis, a larger number of banks were hoarding liquidity during the QE period. Therefore, our empirical sample is likely more representative of the U.S. banking sector.

There have also been some studies on the unintended consequences of QE policies using detailed micro-level data. Kandrac and Schlusche (2021) find that banks increased their level of risk-taking during the QE period as they observe an increase in the growth rate of certain types of high-risk loans. Using a sample of mortgage data, Maggio et al. (2016) study the refinancing channel of QE and find a significant increase in refinancing activities during the QE period when interest rates were relatively low. Acharya et al. (2019) document inefficient lending behavior by banks (i.e., "zombie lending") during the period of the European Central Bank's unconventional monetary policy program. Their results show that such monetary policy does not support the real economy or facilitate economic growth, as firms turn bank loans into cash reserves instead of making real investments. We complement this strand of literature by documenting the consequence of uneven spatial distribution of excess reserves on the growth of business establishments across different regions.

2.Hypothesis Development

We highlight in this section a few key features of the QE period, which significantly altered the

[5] The net-worth channel of monetary policy transmission has also been documented in earlier studies such as Bemanke and Gertler (1989) and Kiyotaki and Moore (1997).

trade-off concerning reserve holding for banks during the financial crisis. This discussion is an attempt to briefly summarize the evolution of reserve distribution in the banking sector, in order to better understand its potential impact on lending for banks in different parts of the reserve distribution.

There are two main ways of reserves introduction by the Fed: loans and LSAP programs. Before the implementation of QE, reserves were mainly introduced through loans from the Fed. Under QE, banks began accumulating reserves through LSAP programs. While loans are available to nearly all banks in the system, LSAP programs only involve a small number of primary dealers. This difference could have contributed to the uneven distribution of reserves across banks at the beginning of the QE period.

Theoretically speaking, banks determine their optimal levels of reserve holdings (and liquid assets in general) by equating the marginal benefits and the marginal costs in question. During the financial crisis, out of concerns about liquidity shortage, banks' demand for reserves increased. Interests on reserves have turned them into a safe liquid asset that generated risk-free returns, increasing the marginal benefits of holding reserves. Meanwhile, the federal funds rate and treasury bill rate (three-month) are very similar to the interest rate on reserves. Given banks' demand for risk-free assets, holding reserves became a viable alternative to engaging in inter-bank lending. Banks also tend to hold liquid assets out of precautionary motives, which are of particular importance during periods of market turmoil. This is because banks with higher levels of reserve holdings are usually perceived as safer by depositors (Acharya and Rajan, 2022). The need to hold more reserves to satisfy regulatory requirements might also be higher during the crisis period. In the meantime, the marginal costs of holding reserves likely decreased as investment opportunities were rare during the crisis, especially after adjusting for risks. As a result, these incentives to hoard liquidity further exacerbated the already uneven distribution of reserves in the banking system.

Under certain conditions, holding large amounts of reserves may have an impact on the effectiveness of monetary policy (Ennis and Wolman, 2010). This line of thinking is related to the bank lending view of monetary transmission a` la Kashyap and Stein (1994). Discussions in the literature are usually based on several assumptions that underpin the ability of a reserve-abundant banking system to increase lending quickly as economic conditions change. First, not only do banks prefer to fund loans with deposits, but it is also costly and time-consuming to expand their deposit base. At the same time, banks are reluctant to reduce their asset sizes as divestment costs could be high. Therefore, banks tend to invest more in liquid assets when good lending opportunities are scarce. Second, as far as borrowers are concerned, substitutes for bank loans are difficult to find, especially in the short run. As Ennis and Wolman (2015) put it, reserve holding can be viewed as a way for banks to "store" deposits that could be used to fund lending in the future. Under these assumptions, a banking system with a large amount of "stored deposits" can expand lending more quickly than one with a lower level of reserves.

Admittedly, the rise in reserve holding across banks does not necessarily translate into more lending, as loans have much higher risk weights than reserves. Diamond et al. (2022) argue that holding reserves could depress lending due to bank balance sheet costs, when regulatory constraints are binding. Even reserve-rich banks may not have the flexibility to expand their lending portfolio, if regulatory requirements, such as capital constraints, are binding. However, banks with higher levels of reserve holdings are perceived as safer by depositors, and therefore, are likely to enjoy lower levels of withdrawal and more stable sources of deposit funding during the crisis, making them more able to comply with regulatory requirements.

We believe that banks' ability to convert liquidity to lending depends crucially on the various

regulatory constraints they face, and hypothesize that banks in different parts of the reserve distribution might respond differently to liquidity changes in terms of lending increase. Cash and reserves, being the most liquid of all assets, could strengthen banks' ability to respond to changes in economic conditions as their levels of liquidity holdings increase. Specifically, we hypothesize that lending responses of banks with high reserve holdings are more sensitive to liquidity changes, while lending of banks with lower reserves might not vary meaningfully with liquidity increases, as liquidity shortage is more of a concern for them.

Furthermore, we hypothesize that the differential responses of bank lending growth to liquidity increases for banks in different parts of the reserve distribution imply vastly unequal impacts on the regional recovery and development across regions. In other words, the uneven distribution of reserves within the banking system across banks during QE could contribute to greater inequality in regional recovery and development across space.

3.Data and Sample

3.1Data source

Given the uneven distribution of reserves across banks, we first examine the differential responses in loan growth in response to liquidity changes for those with higher versus lower levels of reserve holdings. Data on bank balance sheets are available quarterly from the FDIC Consolidated Reports of Condition and Income (i.e., Call Report) for all chartered U.S. banks or bank holding companies. Due to changes in accounting practice, our Call Report sample only includes observations after 2002, totaling 445,069 bank-quarters from 2002Q1 to 2017Q4. Observations with zero reported total assets or equity are dropped. To eliminate the effect of merger and acquisition (M&A) on our key variables, especially growth measures, we exclude bank-quarter observations during which a merger took place.[6] Other data on the Federal Reserve's balance sheet are retrieved from FRED database, which is maintained by the Federal Reserve Bank of St. Louis. We also collect data on the transactions of agency MBS and the U.S. Treasury securities from the Federal Reserve Bank of New York to quantify Fed security purchases during different rounds of QE. To limit the potential impact of outliers, all bank-level financials are winsorized at the 0.5^{th} and 99.5^{th} percentiles of their empirical distributions. In the Robustness Checks section, we obtain syndicated loan data from DealScan and mortgage origination data made public by the Home Mortgage Disclosure Act (HMDA).

Table 1: Bank-Level Summary Statistics

[6] Information on bank mergers and acquisitions is obtained from the National Information Center, which is maintained by the Federal Reserve System. In addition to excluding M&A observations, we also screen our sample in a process similar to those described by Kashyap and Stein (2000), Campello (2002) and Cetorelli and Goldberg (2012).

	All Banks				High-Reserve Banks				Low-Reserve Banks			
	Mean	p(25)	p(50)	p(75)	Mean	p(25)	p(50)	p(75)	Mean	p(25)	p(50)	p(75)
$(Cash + Reserves)/Assets_{it}$	7.317	2.738	4.572	8.790	11.595	5.531	8.775	14.125	3.014	1.998	2.731	3.740
$Liquidity/Assets_{it}$	32.488	19.934	29.542	42.230	35.354	22.584	32.490	45.240	29.603	17.593	26.618	38.783
$dlnNetLoan_{it}$	0.016	-0.012	0.011	0.038	0.012	-0.017	0.007	0.036	0.020	-0.007	0.014	0.039
$dlnC\&ILoan_{it}$	0.013	-0.046	0.003	0.066	0.009	-0.053	0.000	0.064	0.017	-0.040	0.008	0.068
$dlnRELoan_{it}$	0.018	-0.012	0.011	0.038	0.016	-0.016	0.007	0.037	0.021	-0.007	0.013	0.039
$lnAssets_{it}$	18.878	18.012	18.751	19.579	18.591	17.765	18.486	19.276	19.167	18.306	19.019	19.852
$NPL/Assets_{it}$	0.985	0.139	0.504	1.203	1.014	0.109	0.480	1.225	0.957	0.170	0.528	1.185
$Tier1CapitalRatio_{it}$	18.932	11.497	14.180	18.697	20.850	11.966	15.040	20.080	16.987	11.151	13.453	17.300
$NetIncome/Assets_{it}$	0.208	0.119	0.226	0.334	0.192	0.100	0.213	0.327	0.225	0.138	0.237	0.340
Number of bank-quarters	445,069				223,005				221,306			
Number of banks	10,165				9,067				8,719			

Notes: Data are from quarterly FFIEC Call Report forms for all U.S. commercial banks from 2002Q1 to 2017Q4. The same filters are used as in the baseline regressions. A bank is defined as a high-reserve (low-reserve) if its cash and balances due from depository institutions (Schedule RC-A of the Call Report) to total assets ratio is at or above (below) the median in each quarter. Liquidity is calculated as the sum of banks' cash & reserves, and liquid asset

To quantify the real effect of the uneven distribution of reserves on the real economy, we test the relation between local business growth and the market share of banks with high reserve holdings at the county level. We collect business establishment information from the County Business Patterns (CBP), and measure local business growth at both the county-year and the county-industry-year levels. In calculating the market share of different types of banks in each county, we use branch-level deposit information from the FDIC Summary of Deposits (SOD). We also collect relevant county-level socioeconomic characteristics such as unemployment rate, population, and median household income. County-level unemployment rates are from the Local Area Unemployment Statistics (LAUS) program by the U.S. Bureau of Labor Statistics. County-level population and median household income data are obtained from the U.S. Census Bureau's intercensal estimates and Small Area Income and Poverty Estimates (SAIPE) programs, respectively. Panel A and B of Table A1 in the Appendix summarize the county-year and county-industry-year level information used in the analysis of the real effect on the economy, respectively. In these analyses, we exclude finance, insurance, and real estate (FIRE), as well as construction industries due to lack of comparability in their levels of external financing dependence with the rest. Oil and gas industries are also excluded as sectoral employment and growth depend crucially on resource discoveries.

3.2Summary Statistics

Table 1 shows balance sheet information for all banks in the estimation sample as well as subgroups of banks with varying levels of cash & reserve holdings. In general, banks that hold more cash and reserves are slightly smaller on average. Real estate loans tend to grow at a much faster rate than C&I loans over the entire sample period. All sub-groups have tier 1 capital ratios that are greater than 10% on average.

Table 2 presents the balance sheet details for two time periods, before and after the 2007-2008 financial crisis for high- and low-reserve banks, separately.[7] Following the implementation of

[7] Table A2 in the Appendix presents the mean comparisons of all bank characteristics between the high- and low-reserve banks for (i) the full sample period, (ii) the pre-crisis period of 2002-2006, and (iii) the crisis and QE period of 2007-2017, separately in each panel. Banks with high- versus low-levels of reserve holdings appear rather different even along the

the QE policies, banks with both high and low liquidity levels increased their cash and reserve holdings. We do not see a clear trend for the total liquid assets after 2007. Furthermore, we do not see significant changes in the capital positions of the two types of banks following the crisis. This could be attributed in part to the implementation of Basel III capital standards, as well as its annual stress tests and capital planning processes. Moreover, even with QE, average bank loan growth was much lower for both types of banks and all types of loans (i.e., total loans, C&I loans, and real estate loans) in the post-crisis period. This confirms the significant change in the overall economic environment following the crisis. Indeed, nonperforming loans (NPLs) were much higher in the post-crisis period for both high- and low-reserve banks, while net income was much lower.

Table 2: Bank-Level Summary Statistics by Reserve Holding Levels

	High-Reserve Banks								Low-Reserve Banks							
	Pre-Crisis: 2002-2006				Crisis & QE: 2007-2017				Pre-Crisis: 2002-2006				Crisis & QE: 2007-2017			
	Mean	p(25)	p(50)	p(75)	Mean	p(25)	p(50)	p(75)	Mean	p(25)	p(50)	p(75)	Mean	p(25)	p(50)	p(75)
$(Cash + Reserves)/Assets_{it}$	7.534	4.450	5.634	8.122	13.671	7.546	10.834	16.660	2.525	1.995	2.570	3.102	3.260	1.998	2.880	4.417
$Liquidity/Assets_{it}$	34.820	22.851	32.449	44.460	35.639	22.477	32.530	45.668	30.087	18.379	27.360	39.316	29.360	17.212	26.234	38.485
$dlnNetLoan_{it}$	0.021	-0.011	0.016	0.046	0.007	-0.020	0.003	0.030	0.028	-0.002	0.021	0.049	0.015	-0.009	0.011	0.034
$dlnC\&ILoan_{it}$	0.018	-0.047	0.009	0.076	0.004	-0.055	0.000	0.057	0.024	-0.037	0.015	0.079	0.013	-0.041	0.005	0.063
$dlnRELoan_{it}$	0.027	-0.010	0.018	0.053	0.010	-0.018	0.003	0.030	0.032	-0.002	0.022	0.053	0.016	-0.009	0.010	0.033
$lnAssets_{it}$	18.352	17.548	18.239	19.004	18.711	17.891	18.610	19.382	18.910	18.059	18.744	19.574	19.297	18.442	19.148	19.975
$NPL/Assets_{it}$	0.617	0.080	0.333	0.814	1.214	0.133	0.595	1.498	0.589	0.099	0.337	0.778	1.142	0.231	0.663	1.427
$Tier1Capital Ratio_{it}$	17.975	11.270	14.150	19.050	22.320	12.370	15.464	20.610	16.105	10.558	12.790	17.001	17.432	11.490	13.732	17.426
$NetIncome/Assets_{it}$	0.263	0.165	0.263	0.370	0.156	0.072	0.185	0.300	0.279	0.185	0.274	0.371	0.198	0.115	0.217	0.320
Number of bank-quarters	75,033				147,668				73,952				147,138			
Number of banks	7,381				7,602				7,114				7,419			

Notes: Data are from quarterly FFIEC Call Report forms for all U.S. commercial banks from 2002Q1 to 2017Q4. The same filters are used as in the baseline regressions. A bank is defined as a high-reserve (low-reserve) bank if its cash and balances due from depository institutions to total assets ratio is at or above (below) the median in each quarter.

To provide a more complete understanding of banks' liquidity holdings, Figure 1 plots the time series of (1) all liquid assets, as well as (2) cash and reserves, (3) MBS, and (4) Treasury bonds, for the average bank over the 2003-2017 sample period.[8] Given that banks' reserve holdings are likely correlated with their asset sizes, all liquidity measures are normalized by total assets. The shaded areas indicate different rounds of QE. Both the cash and reserve ratio and the overall liquid asset ratio experienced dramatic increases during the QE period, especially during QE1 and QE2.[9] In comparison, the average bank's MBS holding and Treasury holding as a fraction of its total assets stayed relatively stable during the QE period. The shares of MBS and Treasury bond holding were both around 7.5% in the quarter before QE1, and fluctuated around that level during the QE period. In contrast, the cash and reserve ratio had more than doubled by the start of QE3 compared to the pre-QE period, rising from below 5% to above 10%. The overall liquid asset ratio rose from approximately 22.5% at the start of QE1 to 25% by the end of QE3.

We focus on banks' cash and reserve holdings since they are the most directly affected by the

observable dimensions such as size and capital adequacy level, therefore, we focus on split-sample analyses where high- and low-reserve banks are modeled separately.

[8] Cash and reserves data is from RCFD0010 in the Schedule RC-A of the Call Report. Missing values of RCFD0010 are filled using RCFD0071 and RCFD0081 in the Schedule RC—Balance Sheet.

[9] Ennis and Wolman (2015) also find that, instead of substituting reserves for other liquid assets, banks simply increased their overall level of liquidity holding during their study period of QE1 and QE2.

Fed's policies. The liquidity crisis that led to Silicon Valley Bank's collapse also highlights the difference between reserves and other liquid asset holdings such as securities, owing to disparities in their interest rate sensitivities. To understand how the massive increase in reserves is distributed across banks, we look at changes in reserve holdings in different parts of the distribution within the banking system. Figure 2 depicts the time series of banks' cash and reserve holdings during our sample period, with the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles plotted separately. The gaps in cash & reserve ratios between the 10^{th} and 90^{th} percentiles, as well as the 25^{th} and 75^{th} percentiles, give us a sense of the dispersion of reserve holdings across banks. A few generalizations emerge. First, with the implementation of QE, banks' cash and reserve holdings entered a new regime and have yet to return to pre-QE levels. Second, while there has always been a larger gap at the top of the distribution, dispersion in banks' cash and reserve holdings has widened significantly, with the interquartile range more than doubling during this period. Banks at the top of the reserve distribution are becoming increasingly liquidity-rich, while those at the bottom are experiencing a modest increase in liquidity. Figure A1 in the Appendix plots the distribution of cash and reserve holdings separately for large and smaller banks. It shows that such dramatic increase in dispersion of cash and reserve holdings is not a large or small bank phenomenon, but rather a common trend shared by both ends of the size distribution.[10]

4.Empirical Framework and Results

Our goal is to directly test the lending responses of banks with different levels of reserve and cash holdings to liquidity changes during the QE period. As we hypothesize that loan growth of high-reserve banks will be more sensitive to liquidity increase than those with lower reserve holdings, we divide banks into higher- and lower-reserve groups and compare the sub-sample results.

4.1Empirical Specifications

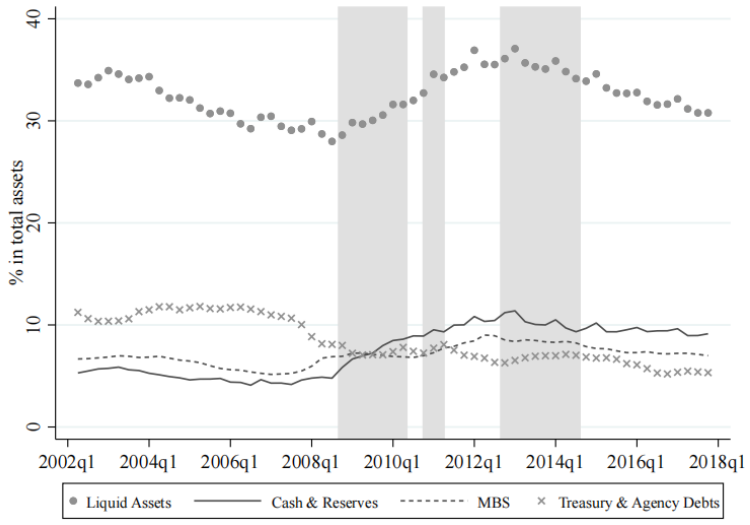
We categorize banks as high- and low-reserve banks based on their cash & reserve ratios (as a share of total assets) based on the quarterly median level cash & reserve holdings of our estimation period.[11] Figure 1 shows that overall liquidity levels rose and fell with the cash & reserves ratio throughout the QE period, consistent with the fact that reserves are most directly affected by Fed policies and interventions. Empirically, we adopt the following model with bank and time fixed-effects, and estimate the model using both OLS and IV methods, separately for high- and low-reserve banks:

$$\Delta lnLoan_{i,t} = \beta * lnLiquidity_{i,t-1} + \sum_{k=1}^{\vec{c}} \rho_k * QE_{k,t-1} * lnLiquidity_{i,t-1} + \lambda * X_{i,t-1} + \mu_i + \gamma_t + \epsilon_{i,t} \quad (1)$$

Figure 1: Changes in Liquidity Levels during QE

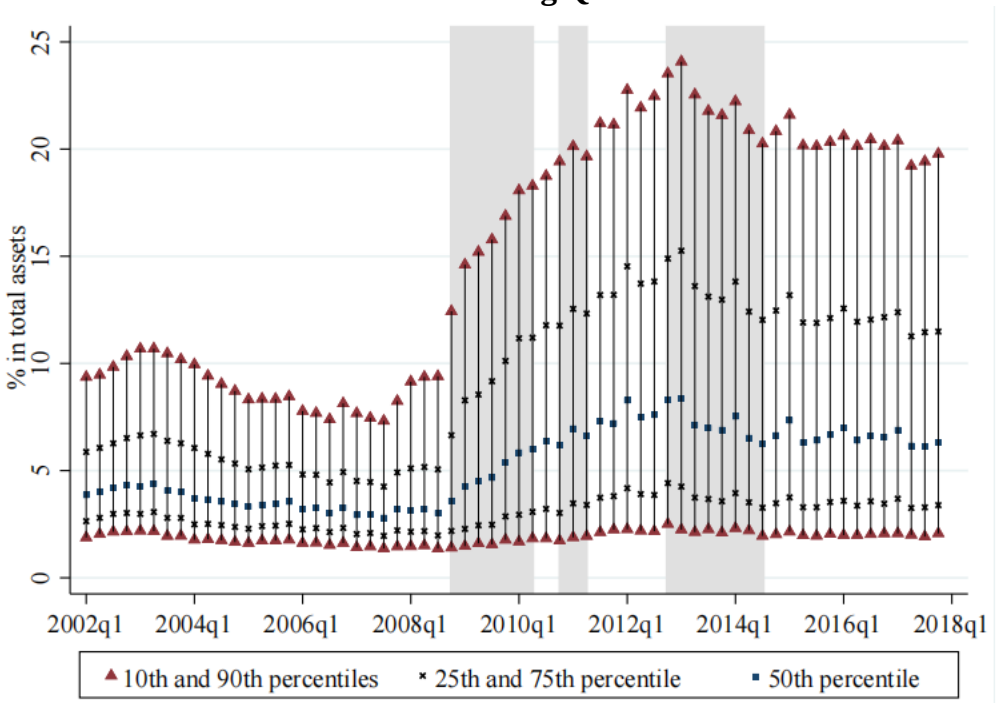
[10] Figure A1 in the Appendix shows that smaller banks have higher levels of cash and reserve holdings (as a fraction of their assets) than large banks both pre-crisis and during the QE episodes, consistent with the precautionary motives of reserve holding being stronger for smaller banks. In addition, the marginal cost of reserve holding during crisis might be even lower for smaller banks as lending opportunities were scarce.

[11] We find similar results with alternative criteria for reserve-constrained banks (i.e., below the 25th percentile) and reserve-rich banks (i.e., above the 75th percentile). Similar results are also obtained using banks' total liquid asset holdings instead of their cash & reserve holdings.



Notes: Data are from quarterly FFIEC Call Report forms for all U.S. commercial banks from 2002Q1 to 2017Q4. Filters used in the baseline regressions are applied. The mean of each variable is plotted for each quarter. Shaded areas indicate the three rounds of QEs starting from 2008Q4. Liquid assets are the outstanding amount of federal funds sold, securities purchased under agreements to resell, held-to-maturity securities, available-for-sale securities, and trading assets, plus cash & reserve holdings. Cash & reserves are defined as cash and balances due from depository institutions (Schedule RC-A in Call Report). MBS is the outstanding amount of mortgage-backed securities. Treasury is the outstanding amount of U.S. Treasury securities, and U.S. government agency obligations excluding MBS.

Figure 2: Distribution of Cash & Reserves during QE



Notes: Data are from quarterly FFIEC Call Report forms for all U.S. commercial banks from 2002Q1 to 2017Q4. Same filters are used as in the baseline regressions. Shaded areas indicate the three rounds of QEs starting from 2008Q4. Cash & reserves are defined as cash and balances due

from depository institutions (Schedule RC-A in Call Report).

where $\Delta lnLoan_{i,t}$ is defined as the growth rate of total lending of bank i in year t, $lnLiquidity_{i,t}$ is a measure of bank i's overall balance sheet liquidity level, defined as the logarithm of a bank's liquid asset ratio, μ_i is a vector of bank fixed effects, and γ_t represents year-quarter fixed effects. Lagged values of banks' asset size, NPL ratio, Tier 1 capital ratio, and net income are included as controls ($X_{i,t-1}$). Bank fixed effects are included to strip away any time-constant bank-specific characteristics associated with their lending behavior. For example, Berger and Roman (2015) find that banks that are beneficiaries of the Troubled Asset Relief Program (TARP) enjoyed competitive advantages and gained market share over non-recipients. The inclusion of bank fixed effects suggests that the identifying variations in our model come from within banks rather than across banks (e.g., TARP recipients vs. non-recipients). We also include a vector of year-quarter fixed effects to remove any economy-wide factors that may affect all banks' lending decisions similarly in each quarter.

To address the potential endogeneity caused by banks' liquidity holdings being correlated with loan cyclicality, we also estimate the model using 2SLS techniques with a quasi-instrument for the liquidity measure following Kashyap and Stein (2000) and Cetorelli and Goldberg (2012). This quasi-instrument is the residual from a regression of the liquidity ratio on the C&I loan ratio and the NPL ratio (both as percentages of total lending). All interactions between the QE indicators and the endogenous liquidity measure are instrumented with their corresponding products.

4.2Empirical Findings

Table 3 presents the results of equation (1) estimated using both OLS and 2SLS.[12] The left panel (columns (1) - (4)) displays full sample (2003-2017) estimates using various methods. The right panel (columns (5) - (8) presents results from the crisis and QE period sample (2007-2017), which we believe is a more appropriate time frame for assessing the differential lending response of banks with varying levels of reserves. We find that loan growth of high-reserve banks are more responsive to the liquidity changes than their low-reserve counterparts (e.g., columns (3) versus (4), and columns (7) versus (8)). Given a 1% increase in liquid asset ratio, the associated additional changes in loan growth for high-reserve banks are about 0.005%, 0.009%, and 0.005% for the three rounds of QE, respectively, compared to the non-QE period (column (3)). Lending responses due to liquidity changes for the low-reserve banks are found to be significantly smaller in magnitude than their high-reserve counterparts. Results for the high-reserve banks are largely similar in the post-2007 sub-sample, while lending growth for the low-reserve banks appear even less responsive than the full sample estimates.

To quantify the economic significance of our findings, we calculate the percentage change in loan growth relative to its sample mean for banks in the two sub-samples. During QE1, a 1% increase in liquidity ratio is associated with a 0.032% increase in loan growth for banks with higher levels of cash and reserve holdings, while only 0.020% for their lower-reserve counterparts.[13] Considering that the full sample mean of loan growth is 1.6%, a 0.032% increase is about 2% of the sample average.

[12] Figure A2 in the Appendix presents the year-by-year coefficient on liquidity in the baseline regression for high- and low-reserve banks separately. The diverging pattern between the high- and low-reserve banks in their lending-liquidity relationship during the QE periods is consistent with the possibility that low-reserve banks tend to increase their liquidity holding during the QE periods out of precautionary motives, including the need to satisfy regulatory requirements.

[13] 0.032%=0.027%+0.005%, as shown in column (5) for high-reserve banks, while 0.020%=0.018%+0.002%, as shown in column (6) for low-reserve banks.

In Table 4, we perform tests similar to the baseline regressions, but replacing the QE indicators with two continuous measures that capture the scale of the Fed's LSAPs. For brevity, we only report results using the post-2007 period sample and only report results estimated with 2SLS for the remainder of the paper. The first measure is based on the actual net purchase amount of agency MBS and Treasury securities, while the second is the size of the Fed's balance sheet. Estimation results for the two measures are reported in columns (1)-(2) and (3)-(4), respectively.We are most interested in the interaction between the net purchase amount and the liquidity ratio. The same pattern holds in that banks with higher levels of reserve holdings are more responsive in their lending to liquidity injections from the Fed's asset purchase than banks with lower levels of reserve holdings.

5.Robustness Checks

In this section, we begin with a robustness test using DealScan data to address concerns about potential confounding factors such as loan demand. As the differential lending responses are rooted in banks' post-crisis liquidity constraints, we also develop a new measure of liquidity constraint based on Home Mortgage Disclosure Act (HMDA) data to show that our findings are robust to alternative measures of liquidity constraint and sample restrictions.

Table 3: Bank Reserve Holding and Lending

	Full Sample: 2002-2017				Crisis & QE: 2007-2017			
	OLS		IV = residual liquidity		OLS		IV = residual liquidity	
	High-Reserve	Low-Reserve	High-Reserve	Low-Reserve	High-Reserve	Low-Reserve	High-Reserve	Low-Reserve
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$lnLiquidity_{t-1}$	0.0255***	0.0170***	0.0269***	0.0183***	0.0304***	0.0218***	0.0309***	0.0226***
	(0.0012)	(0.0013)	(0.0012)	(0.0014)	(0.0013)	(0.0016)	(0.0014)	(0.0016)
$lnLiquidity_{t-1} \times QE1$	0.0068***	0.0029***	0.0053***	0.0020**	0.0039***	0.0012	0.0030***	0.0010
	(0.0011)	(0.0009)	(0.0012)	(0.0010)	(0.0011)	(0.0009)	(0.0011)	(0.0009)
$lnLiquidity_{t-1} \times QE2$	0.0080***	-0.0011	0.0087***	-0.0012	0.0073***	-0.0002	0.0078***	-0.0001
	(0.0015)	(0.0011)	(0.0016)	(0.0012)	(0.0014)	(0.0011)	(0.0015)	(0.0013)
$lnLiquidity_{t-1} \times QE3$	0.0054***	0.0021***	0.0054***	0.0023***	0.0055***	0.0028***	0.0056***	0.0031***
	(0.0010)	(0.0008)	(0.0011)	(0.0008)	(0.0010)	(0.0007)	(0.0010)	(0.0007)
$lnAssets_{t-1}$	-0.0263***	-0.0310***	-0.0265***	-0.0309***	-0.0247***	-0.0349***	-0.0251***	-0.0348***
	(0.0017)	(0.0029)	(0.0018)	(0.0029)	(0.0021)	(0.0021)	(0.0021)	(0.0021)
NPL_{t-1}	-0.0100***	-0.0106***	-0.0100***	-0.0106***	-0.0084***	-0.0087***	-0.0084***	-0.0087***
	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
$Tier1Capital_{t-1}$	0.0008***	0.0008***	0.0008***	0.0008***	0.0006***	0.0009***	0.0006***	0.0009***
	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
$NetIncome_{t-1}$	-0.0111***	-0.0132***	-0.0108***	-0.0131***	-0.0073***	-0.0071***	-0.0071***	-0.0070***
	(0.0010)	(0.0013)	(0.0009)	(0.0013)	(0.0009)	(0.0011)	(0.0009)	(0.0011)
Observations	223,005	221,306	222,309	220,723	147,668	147,138	146,971	146,555
Bank FE	YES	YES	YES	YES	YES	YES	YES	YES
Year-Quarter FE	YES	YES	YES	YES	YES	YES	YES	YES
Anderson-Rubin F Stat	-	-	162.5	58.84	-	-	157.8	63.63
R^2	0.2683	0.3106	0.1578	0.1703	0.2738	0.3191	0.1381	0.1627

Notes: Bank-level data are from quarterly Call Report forms for all U.S. banks from 2002Q1 to 2017Q4. The dependent variable is the first difference of logarithm total loan (ΔlnLoan). Focal independent variables are the interaction terms between the lagged logarithm liquid asset ratio and the lagged QE indicators. Cash and reserve holding is included in the total liquid assets (*lnLiquidity*). QE1 is from 2008Q4 to 2010Q2. QE2 is from 2010Q4 to 2011Q2. QE3 is from 2012Q4 to 2014Q3. A bank is defined as a high-reserve (low-reserve) bank if its cash and balances due from depository institutions (Schedule RC-A of the Call Report) to total assets ratio is above (below) the median in each quarter. IV results are estimated using 2SLS where liquidity level is instrumented by a residual orthogonal to loan cyclicality following Kashyap and Stein (2000). Bank-level controls include total assets (*lnAssets*), non-performing loans as a percentage of total

assets (*NPL*), Tier 1 capital ratio (*Tier*1*Capital*), and net income to total assets ratio (*NetIncome*). Robust standard errors are clustered at the bank level.

5.1Controlling for Loan Demand

Endogeneity associated with unobservable demand-side factors of bank loans is a classic concern in empirical studies of bank lending. Banks' lending may vary due to changes in loan demand rather than their own balance sheet constraints. The underlying logic is that the observed decrease in bank lending could simply be due to decreased loan demand from their customers during economic downturns. To guard against this possibility, we employ the demand control method proposed in Degryse et al. (2019), and estimate our model at the loan level with borrower fixed effects, loan type fixed effects, quarter fixed effects, and industry–location–year fixed effects. In particular, industry-location-year fixed effects are introduced to strip away any cyclicalities that are specific to any industry-market groups.[14] For instance, IT firms in Illinois and California could follow different cycles in their business development and financing needs.

Our loan-level data is constructed using a sample of syndicated loans from the Thomson-Reuters' DealScan, which provides comprehensive historical information on syndicated loan contract details. The data in DealScan are organized by "Package" (or "Deal") and by "Facility". A "Deal" is a contract signed at a specific time between a borrower and one or more lenders. Each syndicated loan deal may include one or more "facilities" (i.e., term loans, bridge loans, lines of credit, leases, etc.), and each "facility" may have one or more lenders. Following existing literature, we treat facilities in each deal as separate loans and conduct our analysis at the syndicated loan level (Qian and Strahan, 2007; Santos, 2011; Ferreira and Matos, 2012). Lenders in the DealScan sample are matched with banks in the Call Report sample using an identifier crosswalk produced by Keil (2018).

Table 4: Robustness Check: Fed Security Purchase and Balance Sheet Size

[14] Industry and location are identified by mergeing DealScan with Compustat using unique identifiers for firms. The crosswalk between DealScan and Compustat firm identifiers are generously shared by Chava and Roberts (2008) online. Due to data availability constraints, we use state to proxy for firm location. The original measure takes into consideration differences in firm size as well. Unfortunately, asset information is only sparsely available in our sample.

	High-Reserve (1)	Low-Reserve (2)	High-Reserve (3)	Low-Reserve (4)
$lnLiquidity_{t-1}$	0.0265***	0.0214***	-0.0380**	-0.0009
	(0.0015)	(0.0018)	(0.0149)	(0.0155)
$lnLiquidity_{t-1} \times lnFedPurchase_{t-1}$	0.0008***	0.0002**		
	(0.0001)	(0.0001)		
$lnLiquidity_{t-1} \times lnFedBalanceSheet_{t-1}$			0.0048***	0.0016
			(0.0010)	(0.0010)
$lnAssets_{t-1}$	-0.0252***	-0.0348***	-0.0247***	-0.0346***
	(0.0021)	(0.0021)	(0.0021)	(0.0022)
NPL_{t-1}	-0.0083***	-0.0087***	-0.0084***	-0.0087***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
$Tier1Capital_{t-1}$	0.0006***	0.0009***	0.0006***	0.0009***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
$NetIncome_{t-1}$	-0.0070***	-0.0071***	-0.0069***	-0.0070***
	(0.0009)	(0.0011)	(0.0009)	(0.0011)
Observations	146,971	146,555	146,971	146,555
Bank FE	YES	YES	YES	YES
Year-Quarter FE	YES	YES	YES	YES
Anderson-Rubin F Stat	315.4	116.4	325.1	128.0
R^2	0.1383	0.1626	0.1382	0.1627

Notes: Bank-level data are from quarterly Call Report forms for all U.S. banks from 2007Q1 to 2017Q4. The dependent variable is the first difference of logarithm total loan (ΔlnLoan). Focal independent variables are the interaction terms between the lagged logarithm liquid assets and the lagged QE policy measures. *FedPurchase* is defined as the actual quarterly purchase amount of the agency MBS and treasury securities by the Fed. *FedBalanceSheeet* is defined as the quarterly balance sheet size of the Fed. Cash and reserves are included in the liquid assets. A bank is defined as a high-reserve (low-reserve) bank if its cash and balances due from depository institutions (Schedule RC-A of the Call Report) to total assets ratio is above (below) the median in each quarter. Results are estimated using 2SLS where liquidity level is instrumented by a residual orthogonal to loan cyclicality following Kashyap and Stein (2000). Bank-level controls include total assets (*lnAssets*), non-performing loans as a percentage of total assets (*NPL*), Tier 1 capital ratio (*Tier*1*Capital*), and net income to total assets ratio (*NetIncome*). Robust standard errors are clustered at the bank level.

Since each facility (i.e., syndicated loan) usually has multiple lenders, we need to compute the precise amount for each lender in each facility. The DealScan data only provide information on the exact loan breakdown for a subset of the facilities. Following De Haas and Van Horen (2012), we divide each facility amount among its lenders using two different rules. First, we employ a straightforward rule that distributes the loan amount evenly among all of its lenders (i.e., "the equal-share rule"). In other words, we assume that all lenders contributed the same amount of money, regardless of their roles in the loan syndication. Alternatively, for the second rule, we attribute half of the loan amount to loan arrangers and the remaining half to loan participants (i.e., "the arranger-half rule").[15] We use loan amounts computed using both rules in all of our

[15] Following Cai et al. (2011), we use the "Lender Role" variable in the DealScan database to identify the role of each lender.

estimations to minimize the impact of measurement errors in the dependent variables. The facility amount in all currencies other than the US dollar is converted to the US dollar using the exchange rate information in DealScan. We also identify each facility's unique borrower. The empirical specification is similar to equation (1), where the computed lender-specific loan amount is the dependent variable.

Table 5 presents results obtained using DealScan data along with lender-level controls and various fixed effects. Columns (1)-(2) show the results for loan amounts allocated using the arranger-half rule, and columns (3)-(4) those allocated using the equal-share rule. The coefficients for the interactions between the liquidity measure and the QE indicators are positive and significant only for the high-reserve group. Banks with higher reserve and cash holdings are found to be more responsive in their lending to liquidity injection even after controlling for unobservable time-varying demand-side factors.[16]

5.2 Alternative Measures for Liquidity Constraint

As the differential lending responses are a result of variations in banks' post-crisis liquidity constraints, we develop a novel proxy for individual bank's liquidity constraints based on its mortgage lending exposure in the hardest-hit housing markets in the subprime mortgage crisis. We exploit cross-bank differences in real estate lending and demonstrate that our findings are robust to alternative measures of liquidity constraint and sample restrictions.

Table 5: Robustness Check: Controlling for Loan Demand

	lnLoan by arranger-half rule		lnLoan by equal-share rule	
	High-reserve	Low-reserve	High-reserve	Low-reserve
	(1)	(2)	(3)	(4)
$lnLiquidity_{t-1}$	−0.0169	0.0002	−0.0085	0.0115
	(0.0255)	(0.0319)	(0.0262)	(0.0281)
$lnLiquidity_{t-1}$ × QE1	0.0729**	−0.0845***	0.0618**	−0.1005***
	(0.0324)	(0.0237)	(0.0266)	(0.0235)
$lnLiquidity_{t-1}$ × QE2	0.0194***	0.0214	0.0269***	0.0094
	(0.0053)	(0.0489)	(0.0024)	(0.0453)
$lnLiquidity_{t-1}$ × QE3	−0.0458	0.0047	0.0441	−0.0180
	(0.1128)	(0.0467)	(0.0866)	(0.0373)
$lnAssets_{t-1}$	0.0705***	0.1112***	0.0541***	0.0977***
	(0.0094)	(0.0109)	(0.0081)	(0.0127)
NPL_{t-1}	0.0204	0.0339***	0.0268	0.0390***
	(0.0248)	(0.0099)	(0.0214)	(0.0091)
$Tier1Capital_{t-1}$	0.0012**	0.0032***	0.0012**	0.0032***
	(0.0005)	(0.0006)	(0.0005)	(0.0006)
$NetIncome_{t-1}$	−0.0873**	−0.1184***	−0.1114***	−0.0628**
	(0.0398)	(0.0286)	(0.0376)	(0.0243)
Observations	10,233	17,115	10,233	17,115
Borrower FE	Yes	Yes	Yes	Yes
Loan Type FE	Yes	Yes	Yes	Yes
Industry–state–year FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
R^2	0.8767	0.7678	0.8826	0.7699

[16] The estimated coefficients differ slightly from those obtained using bank-level data for the following reasons. First, our estimation sample is limited to banks that have done syndicated lending during this time period, which may be a subset of banks. Second, syndicated lending includes some cross-border and foreign loans that may be affected by QE via different channels than domestic loans (e.g., push and pull factors of cross-border banking capital flows). For more information on this topic, see, for example, De Haas and Van Horen (2012) and Giannetti and Laeven (2012).

Notes: Bank-level data are from the Call Report and the DealScan from 2007Q1 to 2017Q4. The dependent variable is the logarithm syndicated loan amount reported in the DealScan. Focal independent variables are the interaction terms between the lagged logarithm liquid assets and the QE indicators. Arranger-Half Rule and Equal-Share Rule are two different rules used to calculate each bank's actual loan amount in each facility when the share information is not available in the DealScan. Cash and reserves are included in the liquid assets. The definitions of QE1, QE2 and QE3 are the same as in the previous tables. A bank is defined as a high-reserve (low-reserve) bank if its cash and balances due from depository institutions to total assets ratio is above (below) the median in each quarter. Borrower fixed effects, loan type fixed effects, industry-state-year fixed effects, and quarter fixed effects are included in all regressions. Bank-level controls include total assets (*lnAssets*), non-performing loans as a percentage of total assets (*NPL*), Tier 1 capital ratio (*Tier*1*Capital*), and net income to total assets ratio (*NetIncome*). Robust standard errors are clustered at the loan type and industry-state-year levels.

The idea is to compare real estate lending responses to liquidity changes for banks that are (1) similarly active in the real estate market, but (2) have different exposure to the hardest-hit markets. Housing markets are intensely local, and there is considerable variation between local housing markets throughout both boom and bust. The geographical coverage of banks in local housing markets is substantially pre-determined by the existence of physical branches. Banks with inadequate liquidity likely cannot respond to new lending possibilities if they have pre-existing positions that may increase the demand for liquidity. By looking at banks' concentration in the hardest-hit markets, we are able to differentiate banks with similar lending composition (i.e., C&I versus real estate loans) and likely comparable along other dimensions, but differ in their ability to react to new lending opportunities due to their liquidity constraints from differential exposure to the hardest-hit markets.

Another advantage of comparing the lending behavior of active real estate lenders is the increased comparability of banks in the sample. Omitted variables, whether observable or not, that are correlated with both banks' liquidity level and lending response pose a potential concern for the comparison of the lending responses of high- and low-reserve banks. For example, banks that differ in their risk preferences might behave differently in their liquidity holdings (including cash, reserves, and other liquid assets). At the same time, banks' attitude towards risks also influences their lending decision as well as their lending responses to liquidity shocks. Since risk preference is difficult to measure or observe, the observed differential lending sensitivity during the QE period between high- and low-reserve banks could be attributable to differences in risk preferences. By restricting the comparison to active real estate lenders, we look at banks that are more comparable with regard to risk-taking and other unobservable characteristics. The main difference that drives banks' liquidity constraint is their differential exposure in the hardest-hit markets, which is, to a large extent, pre-determined.

Table 6: Robustness Check: Alternative Measure of Liquidity Constraint

	Dependent Variable = ΔlnLoan(Real Estate)		
	Sample = High Real Estate Lending Banks		
	All	Exposure Low	Exposure High
	(1)	(2)	(3)
$lnLiquidity_{t-1}$	0.0058***	0.0049***	0.0163***
	(0.0011)	(0.0012)	(0.0041)
$lnLiquidity_{t-1}$ × QE1	0.0020*	0.0024**	-0.0024
	(0.0012)	(0.0012)	(0.0049)
$lnLiquidity_{t-1}$ × QE2	0.0010	0.0009	0.0041
	(0.0015)	(0.0015)	(0.0078)
$lnLiquidity_{t-1}$ × QE3	0.0035***	0.0039***	-0.0028
	(0.0010)	(0.0010)	(0.0059)
$lnAssets_{t-1}$	-0.0193***	-0.0195***	-0.0192***
	(0.0018)	(0.0019)	(0.0062)
NPL_{t-1}	-0.0074***	-0.0074***	-0.0069***
	(0.0002)	(0.0002)	(0.0007)
$Tier1Capital_{t-1}$	0.0015***	0.0014***	0.0022***
	(0.0002)	(0.0002)	(0.0006)
$NetIncome_{t-1}$	-0.0011	-0.0008	-0.0026
	(0.0008)	(0.0009)	(0.0021)
Observations	85,983	79,555	6,427
Bank FE	YES	YES	YES
Year-Quarter FE	YES	YES	YES
Anderson-Rubin F Stat	12.95	10.87	4.767
R^2	0.1822	0.1732	0.2338

Notes: Bank-level data are from quarterly Call Report forms for all U.S. banks from 2007Q1 to 2017Q4. Mortgage lending information is from the Home Mortgage Disclosure Act (HMDA) data. The dependent variable is the first difference of logarithm total loan (loan growth). Focal independent variables are the interaction terms between the lagged logarithm liquid assets and the QE indicators. Cash and reserves are included in the liquid assets. Banks with high real estate lending are those with above-median share of real estate lending in total lending during the period before QE1 (i.e. 2006-2007). "Exposure Low" are those with lower than 50% of loan originated in the hardest hit markets during 2007-2009, while "Exposure High" are those with at least 50% from the hardest hit markets. The definitions of QE1, QE2 and QE3 are the same as in the previous tables. Results are estimated using 2SLS where the liquidity level is instrumented by a residual orthogonal to loan cyclicality. Bank-level controls include total assets (*lnAssets*), non-performing loans as a percentage of total assets (*NPL*), Tier 1 capital ratio (*Tier*1*Capital*), and net income to total assets ratio (*NetIncome*). Robust standard errors are clustered at the bank level.

We first identify the hardest-hit housing markets during the subprime mortgage crisis by examining changes in the county-level HPI between 2007 and 2009.[17] We rank counties according to changes in the HPI and designate the bottom 5% as the hardest-hit markets. In order to measure mortgage origination for each lender, we aggregate mortgage applications to the lender-county-year level.[18] We apply the conventional sample restriction and include in our sample single-family first lien loans for purchase or refinance.

As the goal is to identify banks that are most severely affected by the collapse of the housing market during the subprime mortgage crisis, we quantify banks' housing market activity based on

[17] Alternative time windows such as 2007-2008 and 2008-2009 yield similar results.

[18] Lender information in the Call Report and the mortgage lending information in HMDA are matched using the crosswalk developed and generously shared by Robert Avery of the Federal Housing Finance Agency (FHFA).

their real estate lending during the boom era preceding the collapse. Specifically, we first categorize banks as active real estate lenders if the proportion of real estate to total lending during the period preceding QE1 (i.e., 2006-2007) is above the sample median. We then calculate for each bank the share of mortgage originated in most adversely affected counties over their total origination for the year. High-exposure banks are defined as those that have originated more than 50% of their mortgages in the bottom 5% of counties in terms of HPI changes.

Table 6 presents the results for net real estate loan growth for all active real estate lenders (column (1)), and separately for those with high- and low-exposure in the hardest-hit markets (columns (2) and (3)). First, these results validate the comparability of the sample, which consists of banks that are actively involved in the real estate market and whose real estate lending is highly sensitive to changes in their liquidity levels. Less affected banks increased their real estate lending in response to liquidity increase as a result of the QE policies, while those with a high share of mortgages originated in the hardest-hit markets were not able to do so.

6.Real Effects on the Economy

To understand the broader implication of such uneven distribution of bank reserves, we assess the real effects of differential lending responses using data from the County Business Patterns. We hypothesize that the differential responses of bank lending growth to liquidity increases for banks in different parts of the reserve distribution could result in vastly unequal impacts on the regional recovery and development across locations. To test this hypothesis, we first measure the market share of high-reserve banks for each county-year using deposit information at the branch level reported in SOD, and estimate the following model of local business growth for county c in year t:

$$\%\Delta Establishments_{ct} = \beta * I(\%HighReserveBanks^{High})_{c,t-1} + \rho * lnDeposits_{c,t-1} + \lambda * X_{c,t-1} + \mu_c + \gamma_t + \epsilon_{ct}, \quad (2)$$

where $\%\Delta Establishments_{ct}$ is the growth rate of number of establishments in county c year t, $I(\%HighReserveBanks^{High})_{c,t-1}$ is an indicator for an above-median market share held by high-reserve banks for county c in year $t-1$, $lnDeposits_{c,t-1}$ is the logarithm of total deposits in county c year $t-1$. We also control for relevant county-level socioeconomic characteristics such as unemployment rate, population, and median household income ($X_{c,t-1}$). County and year fixed effects are included to control for any time-invariant heterogeneities in local business growth across counties and any year-to-year variations in the macro environment common to all.

To examine more closely any industry-market level heterogeneities in local business growth patterns, we also estimate a model similar to equation (2) at the county-industry-year level. The dependent variable is $\%\Delta Establishments_{cjt}$ - the growth rate of number of establishments in county c industry j year t - and the vectors of county fixed effects (μ_c) and year fixed effects (γ_t) are replaced with county-industry pair fixed effects (μ_{cj}) and industry-year fixed effects (γ_{jt}). These two sets of fixed effects should account for any time-constant heterogeneities specific to a industry-market pair, and any industry-specific national trends in local business growth.

Table 7 presents the real effects of the uneven distribution of bank reserves on local business growth. Column (1) of Panel A reports results at the county-year level, while columns (2) to (4) report the county-industry-year level results. Counties with a larger market share captured by high-reserve banks appear to enjoy a higher rate of local business growth. Specifically, the coefficients of interest are 0.115 and 0.143 for the county-year and county-industry-year models, respectively. In counties with an above-median share of high-reserve banks, the growth rate of number of establishments is approximately 0.115 percentage points higher. To put this magnitude into context, the average county-level annual growth rate in the number of

establishments in our estimation sample is 0.045%, and the interquartile range is 3.342%. We further differentiate between industries with varying levels of external financing dependence following Duygan-Bump et al. (2015) and Gilje (2019). Results are reported in columns (3) and (4) of Panel A in Table 7. The estimated coefficient of interest is only statistically significant for industries that are more dependent on external financing, suggesting that firms in these industries benefit more from the local presence of high-liquidity banks.

We also conduct a falsification test using large banks, rather than high-reserve banks, as one might be concerned that the result is reflective of a mere size effect, since large banks may hold more reserves. We define a large bank as banks whose assets are at or above the 95^{th} percentile in a given quarter of the sample period, following Kashyap and Stein (2000), Campello (2002) and Cetorelli and Goldberg (2012). We then calculate the market share of large banks in each county-year. In the empirical specification, the indicator $I(\%HighReserveBanks^{High})_{c,t-1}$ in equation (2) is replaced by $I(\%LargeBanks^{High})_{c,t-1}$, which is an indicator for an above-median market share held by large banks for county c in year $t-1$. Results are reported in Panel B of Table 7. We do not find any statistically significant association between local business growth and the market share of large banks at the county level, indicating that the banks' reserve-holding effect on the local economy is different from the size effect.

7.Conclusion

This paper examines the differential lending responses of banks with varying levels of reserves, and their impact on the real economy. We start by documenting the uneven distribution of reserves in the U.S. banking system as a result of the Federal Reserve's unconventional monetary policies. Not only has the overall reserve level increased as a result of the Fed's intervention, but the dispersion in reserve holdings across banks has also grown with the three rounds of QE. Reserve hoarding by banks during the financial crisis has further widened the liquidity gap between high- and low-reserve banks. We believe that banks' ability to convert liquidity to lending depends crucially on the various regulatory constraints they face, and hypothesize that banks in different parts of the reserve distribution might respond differently to liquidity changes in their lending increase.

Table 7: Effects of Bank Reserve Holding on Business Establishments

	Dependent Variable = %Δ(*Establishments*)			
	County-Year	County-Industry-Year		
		All Sectors	External Finance Dependence High	External Finance Dependence Low
	(1)	(2)	(3)	(4)
		Panel A: Establishment Results		
$I(\%HighReserve^{High})_{t-1}$	0.1152***	0.1434**	0.1578*	0.1261
	(0.0372)	(0.0586)	(0.0809)	(0.0848)
$lnDeposits_{t-1}$	-0.0452	0.2000	-0.0058	0.4389*
	(0.1223)	(0.1817)	(0.2431)	(0.2550)
$Unemployment_{t-1}$	-0.2134***	-0.1782***	-0.2282***	-0.1198***
	(0.0178)	(0.0250)	(0.0349)	(0.0311)
$lnPopulation_{t-1}$	-8.3399***	-7.8116***	-9.5783***	-5.7581***
	(0.6009)	(0.8082)	(1.0989)	(1.1202)
$lnHouseholdIncome_{t-1}$	-1.5048***	-2.9972***	-5.1849***	-0.4176
	(0.3960)	(0.5811)	(0.7496)	(0.8253)
Observations	36,059	513,404	276,191	237,213
R^2	0.2312	0.0757	0.0771	0.0740
	Panel B: Falsification Results			
$I(\%Large^{High})_{t-1}$	0.0254	-0.0232	-0.0187	-0.0289
	(0.0605)	(0.1018)	(0.1319)	(0.1521)
$lnDeposits_{t-1}$	0.0033	0.2665	0.1660	0.3818
	(0.1226)	(0.1851)	(0.2389)	(0.2679)
$Unemployment_{t-1}$	-0.1898***	-0.1455***	-0.1752***	-0.1108***
	(0.0167)	(0.0247)	(0.0339)	(0.0325)
$lnPopulation_{t-1}$	-8.4342***	-8.1100***	-9.4710***	-6.5367***
	(0.5989)	(0.8191)	(1.0928)	(1.1898)
$lnHouseholdIncome_{t-1}$	-1.6066***	-2.3444***	-3.8143***	-0.6269
	(0.3794)	(0.6150)	(0.7492)	(0.8915)
Observations	31,621	456,317	244,892	211,425
R^2	0.2648	0.0684	0.0700	0.0667
County FE	YES			
Year FE	YES			
Industry-year FE		YES	YES	YES
County-industry FE		YES	YES	YES

Notes: Data are from the County Business Patterns and the FDIC Summary of Deposits (SoD). The dependent variable %Δ*Establishments* is the growth rate of the number of establishments at the county-year level in column (1), and at the county-industry-year level in columns (2)-(4). In Panel A, $I(\%HighReserve^{High})$ is an indicator for an above-median market share held by high-reserve banks. *lnDeposits* is the logarithm of total deposits. County-level controls include the unemployment rate, the logarithm of the total population, and the logarithm of median household income. In Panel B, $I(\%Large^{High})$ is an indicator for an above-median market share held by large banks, where large banks are those whose assets are at or above the 95^{th} percentile in a given quarter of the sample period. County and year fixed effects are included in column (1). County-industry and industry-year fixed effects are included in columns (2)-(4). Robust standard errors are clustered at the county level.

We find that loan growth for the more liquidity-constrained banks does not vary meaningfully with liquidity changes, despite excess liquidity in the aggregate level. Only high-reserve banks are found to be responsive in their lending to changes in banks' overall liquidity levels. Using DealScan data, we demonstrate the robustness of our results by controlling for time-varying industry-market-specific demand factors at the loan level. We also construct novel measures of liquidity constraint using individual bank's exposure to the hardest-hit housing markets using HMDA data, and find our main results to be unchanged. In addition, we find that the differential responses of bank lending growth to liquidity increases for banks with different levels of reserves could translate into unequal regional development at the county level. Counties with a larger

market share captured by high-reserve banks experienced higher local business growth, with this finding being more pronounced for the more external-financing-dependent industries. Our results highlight a potential consequence of the increased dispersion in reserve distribution across banks as a result of the QE policies, as the significant difference in loan growth across banks could lead to greater spatial disparity in regional development.

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Appendix

Table A1: County-Level Summary Statistics

County-level summary statistics.

	N	Mean	p(25)	p(50)	p(75)
	Panel A: County–year				
$\%\Delta(Establishments)_{ct}$	36,059	0.045	−1.695	0	1.647
$I(\%HighReserveBanks^{High})_{ct}$	36,059	0.504	0	1	1
$lnDeposits_{ct}$	36,059	13.096	12.138	12.927	13.842
$Unemployment_{ct}$	36,059	6.594	4.500	6.000	8.100
$lnPopulation_{ct}$	36,059	10.434	9.516	10.312	11.256
$lnHouseholdIncome_{ct}$	36,059	10.658	10.492	10.641	10.806
$\%\Delta(Establishments)_{cjt}$	Panel B: County–industry–year				
– All sectors	513,404	0.060	−1.639	0	1.622
– External finance dependence high	276,191	0.06	−1.648	0	1.628
– External finance dependence low	237,213	0.061	−1.630	0	1.617

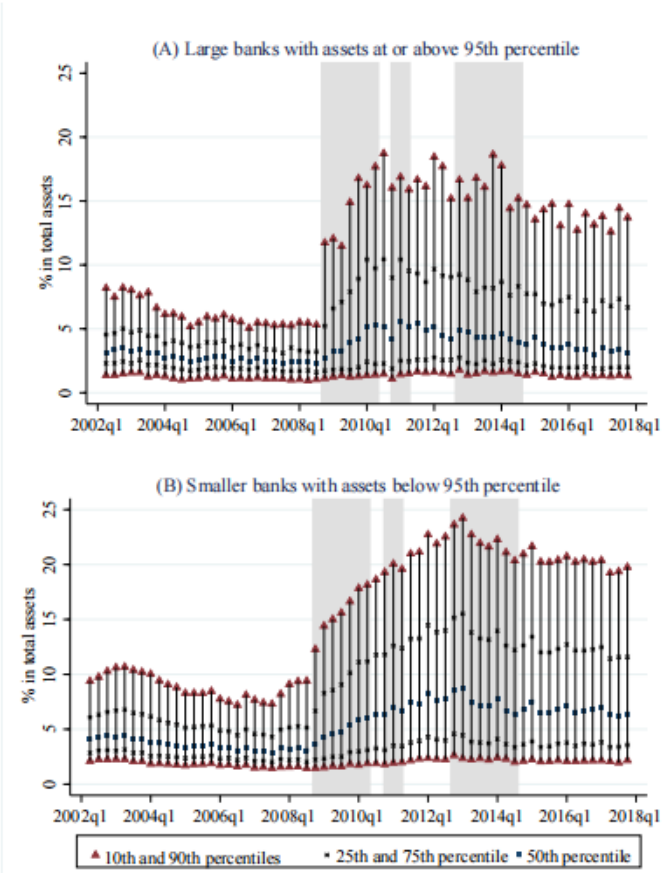
Notes: Panel A and B summarize the county-year and county-industry-year level information used in the analysis of the real effect on the economy, respectively. Business establishment data are from the County Business Patterns (CBP). Branch-level deposit information is from the FDIC Summary of Deposits (SOD). $\%\Delta Establishments_{ct}$ is the growth rate of number of establishments in county *c* year *t*, $I(\%HighReserveBanks^{High})_{ct}$ is an indicator for having an above-median market share held by high- reserve banks in terms of deposits for county *c* in year *t*. $lnDeposits_{ct}$ is the logarithm of total deposits in county *c* year *t*. County-level unemployment rates are from the Local Area Unemployment Statistics (LAUS) program by the U.S. Bureau of Labor Statistics. County-level population and median household income data are obtained from the U.S. Census Bureau's intercensal estimates and Small Area Income and Poverty Estimates (SAIPE) programs, respectively. In Panel B, industries are categorized into two groups based on their levels of external financing dependence following Duygan-Bump et al. (2015) and Gilje (2019).

Table A2: Mean Comparison of Bank Characteristics

	High-Reserve Banks		Low-Reserve Banks		T-Test	
	Mean	Std Dev	Mean	Std Dev	Diff	t-value
			Panel A: Full Sample			
$(Cash + Reserves)/Assets_{it}$	11.586	9.132	3.015	1.467	-8.571***	(-437.940)
$Liquidity/Assets_{it}$	35.345	17.015	29.608	16.327	-5.737***	(-114.770)
$dlnNetLoan_{it}$	0.012	0.063	0.020	0.057	0.008***	(43.479)
$dlnC\&ILoan_{it}$	0.009	0.162	0.017	0.147	0.008***	(17.991)
$dlnRELoan_{it}$	0.016	0.073	0.021	0.065	0.006***	(26.699)
$lnAssets_{it}$	18.592	1.271	19.166	1.316	0.573***	(147.827)
$NPL/Assets_{it}$	1.013	1.551	0.957	1.343	-0.056***	(-12.800)
$Tier1CapitalRatio_{it}$	20.851	31.659	16.998	20.667	-3.853***	(-48.117)
$NetIncome/Assets_{it}$	0.192	0.404	0.225	0.340	0.033***	(29.309)
Number of bank-quarters	223,408		221,661			
			Panel B: Pre-Crisis: 2002-2006			
$(Cash + Reserves)/Assets_{it}$	7.508	5.929	2.528	0.807	-4.980***	(-228.166)
$Liquidity/Assets_{it}$	34.769	16.165	30.086	16.063	-4.683***	(-56.144)
$dlnNetLoan_{it}$	0.021	0.069	0.028	0.063	0.007***	(19.676)
$dlnC\&ILoan_{it}$	0.018	0.165	0.024	0.157	0.006***	(6.674)
$dlnRELoan_{it}$	0.027	0.081	0.032	0.073	0.004***	(10.839)
$lnAssets_{it}$	18.355	1.228	18.910	1.292	0.554***	(84.965)
$NPL/Assets_{it}$	0.617	0.878	0.589	0.809	-0.028***	(-6.472)
$Tier1CapitalRatio_{it}$	17.813	19.261	16.039	17.260	-1.774***	(-18.745)
$NetIncome/Assets_{it}$	0.262	0.297	0.279	0.261	0.017***	(11.469)
Number of bank-quarters	75,186		74,085			
			Panel C: Crisis & QE: 2007-2017			
$(Cash + Reserves)/Assets_{it}$	13.649	9.741	3.261	1.651	-10.388***	(-404.613)
$Liquidity/Assets_{it}$	35.622	17.404	29.362	16.441	-6.260***	(-100.517)
$dlnNetLoan_{it}$	0.007	0.059	0.015	0.052	0.008***	(40.786)
$dlnC\&ILoan_{it}$	0.004	0.160	0.014	0.141	0.010***	(17.543)
$dlnRELoan_{it}$	0.010	0.067	0.016	0.060	0.006***	(26.354)
$lnAssets_{it}$	18.713	1.275	19.295	1.309	0.582***	(122.378)
$NPL/Assets_{it}$	1.215	1.765	1.142	1.509	-0.072***	(-11.920)
$Tier1CapitalRatio_{it}$	22.308	35.992	17.437	21.959	-4.871***	(-44.432)
$NetIncome/Assets_{it}$	0.156	0.443	0.197	0.370	0.042***	(27.701)
Number of bank-quarters	148,100		147,471			

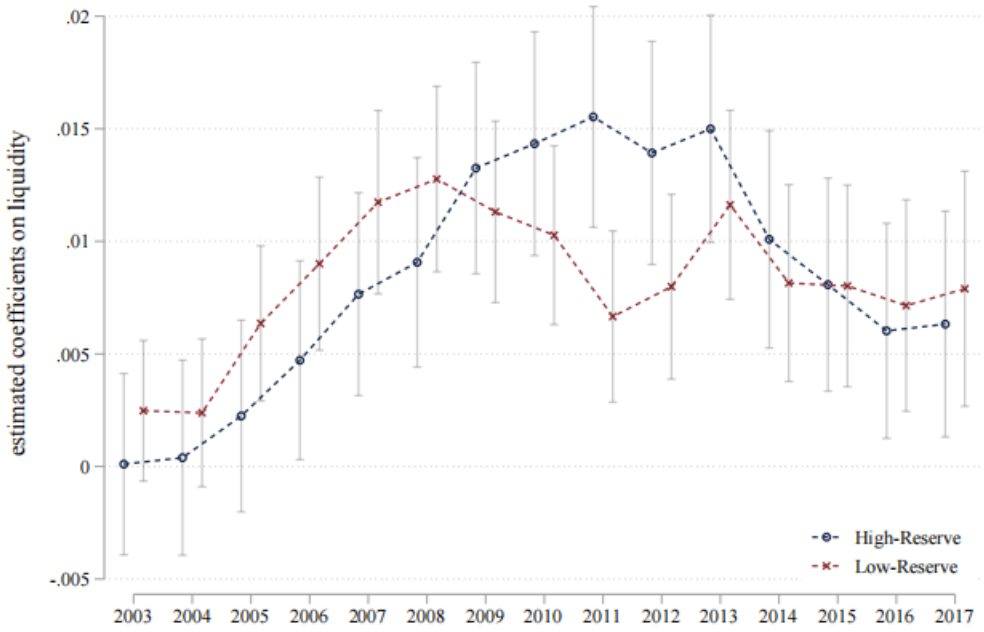
Notes: Data are from quarterly FFIEC Call Report forms for all U.S. commercial banks from 2002Q1 to 2017Q4. Same filters are used as in the baseline regressions. A bank is defined as a high (low)-reserve if its cash and balances due from depository institutions (Schedule RC-A of the Call Report) to total assets ratio is above (below) the median in each quarter. Liquidity is calculated as the sum of banks' cash & reserves, and liquid assets. Slight discrepancies in the numbers of observations between this table and Table 3 are due to singleton groups being omitted from fixed effect regressions.

Figure A1: Distribution of Cash & Reserves during QE: Large versus Smaller Banks



Notes: This figure plots the within group distribution of cash & reserve holdings (as a fraction of total assets) for our sample period of 2002Q1 to 2017Q4, separately for large and smaller banks, similar to Figure 2. Large (smaller) banks are defined as those at or above (below) the 95^{th} percentile in bank assets in a given quarter. Similar patterns are obtained using constant thresholds such as 300 millions in assets.

Figure A2: Year-by-Year Coefficient Plot of the Lending-Liquidity Regressions



Notes: The year-by-year coefficients on liquidity are estimated in a version of the baseline regression where the interaction terms between QE indicators and liquidity are replaced with the interaction terms between a series of year indicators and liquidity, separately for high- and low-reserve banks with year 2002 as the reference point.